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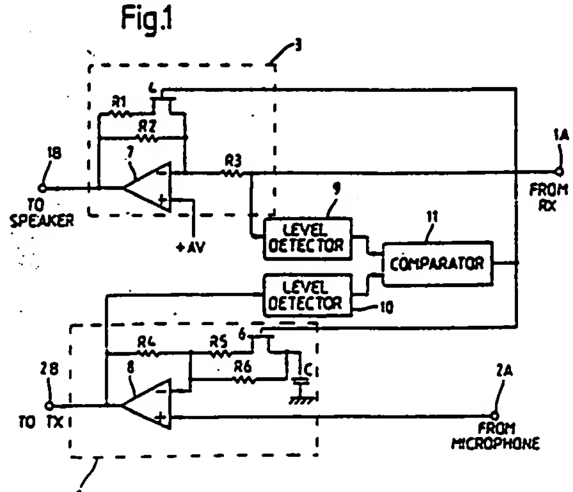
(54) Loudspeaking telephone with a variable gain circuit.

FOREIGNS

(57) A loudspeaking telephone with a variable gain circuit includes a receiving path having means for amplifying a received signal by a first amount of gain to provide a received speech signal, a transmitting path having means for amplifying a transmitted speech signal by a second amount of gain to provide a transmitted signal, first means for comparing a signal level in the received signal path with a signal level in the transmitted signal path to provide a control signal to control the first and the second amounts of gain, and second means responsive to the control signal for switching between the first and the second amounts of gain to make one of the amounts of gain larger than the other amount of gain, wherein the total gain obtained from the first and the second amounts of gain during the changeover period of the gains is either equal to or smaller than the total gain during the stable period, excluding the changeover period.

Fig.1



EP 0 298 719 A2

LOUDSPEAKING TELEPHONE WITH A VARIABLE GAIN CIRCUIT

BACKGROUND OF THE INVENTION

The present invention relates to a loudspeaking telephone utilizing a microphone and a loudspeaker, and more particularly, to a loudspeaking telephone with a variable gain circuit for controlling the gains in the receiving and transmitting paths.

In the prior art speakerphone, the gains in the receiving and transmitting paths are switched by means of a variable resistance element, such as a field effect transistor (FET), in response to the values of the receiving and transmitting signal levels. In order to avoid the singing or howling, it is preferable that the product of the gains in the receiving and transmitting paths, called as the total gain, is always constant.

In the prior art loudspeaking telephone, however, the total gain is not necessarily constant due to the variations of the gate voltage versus conducting resistance characteristics of the FET which determines the gains in the receiving and transmitting paths. Namely, under "a stable period" during which the gains in the receiving and transmitting paths are stable, the total gain is constant. On the contrary, under "a changeover period" during which the gains in the receiving and transmitting paths are switched, the total gain may increase due to the forementioned variations of the characteristics. This results, that the howling or singing problem may occur.

The prior art loudspeaking telephone is described in the following papers:

(1) A. Busala, "Fundamental Consideration in the Design of a Voice-Switched Speakerphone, "THE BELL SYSTEM TECHNICAL JOURNAL, Vol. XXXIX, March 1960, pp. 265 -294; and

(2) W.F. Clemency et al, "Functional Design of a Voice-Switched Speakerphone, "THE BELL SYSTEM TECHNICAL JOURNAL, Vol. XL, May 1961, pp. 649 - 668.

(3) U.S. Patent No. 4 [illegible]29.829 issued to Puhl et al, December 16, 1986.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a loudspeaking telephone for suppressing the increase of the total gain during the changeover period of the gain so as to prevent the singing or howling.

According to the present invention, there is provided a loudspeaking telephone with a variable gain circuit comprising: a receiving path including first amplifying means for amplifying a receiving signal by a first gain to provide a receiving speech signal, a transmitting path including second amplifying means for amplifying a transmitting speech signal by a second gain to provide a transmitting signal, first means for comparing a signal level on said receiving path with a signal level on the transmitting path to provide a control signal to control the first and the second gains and second means responsive to the control signal for switching between the first and second gains to make one of the gains larger than the other of the gains, wherein the total gain obtained from the first and second gains during the changeover period of the gains is either equal to or smaller than the total gain during the stable period excluding the changeover period.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described in further detail below with reference to the accompanying drawings in which:

Fig. 1 is a schematic diagram showing the first embodiment of the loudspeaking telephone according to the present invention;

Fig. 2 is a schematic diagram showing the second embodiment of the loudspeaking telephone according to the present invention; and

Fig. 3 is a graph showing the gate voltage versus gain characteristics of the embodiment shown in Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In Fig. 1, the paths from terminal 1A to 1B and from terminal 2A to 2B are the receiving and the transmitting paths, respectively. When this embodiment is applied to the mobile telephone, the terminals 1A and 1B are connected to a receiver (RX) and a loudspeaker, respectively, while the terminals 2A and 2B are connected to a microphone and a transmitter (TX), respectively. A receiving variable gain amplifier circuit 3 comprises an operational amplifier 7 acting as an inverting amplifier. The circuit 3 amplifies a receive signal from terminal 1A to produce an amplified signal and supply it to the terminal 1B as a receive speech signal. A serial connection of an FET 4 and a resistor R_1 is connected in parallel with a feedback resistor R_2 of the amplifier 7. A transmitting variable gain amplifier circuit 5 comprises an operational amplifier 8 acting as a non-inverting amplifier. The circuit 5 amplifies a transmit speech signal from 2A to produce an amplified signal and supply it to the terminal 2B as a transmit signal. A serial connection of an FET 6 and a resistor R_5 is connected in parallel with an inverting input resistor R_6 of the amplifier 8. The connection point of the FET 6 and the resistor R_6 is connected to the ground through a capacitor C.

The receive signal level is detected by a receiving level detector 9, while the transmit signal level is detected by a transmitting level detector 10. The detected results of detectors 9 and 10 are compared with each other by a comparator 11. In response to the comparison result, the comparator 11 supplies the gates of the FETs 4 and 6 with a control voltage, by which both FETs 4 and 6 are switched off if the output level of the receiving level detector 9 is higher than the output level of the transmitting level detector 10 and otherwise they are switched on.

When the FETs 4 and 6 are off, their resistance values are substantially infinite. In this case, the feedback resistor of the operational amplifier 7 is only R_2, resulting in that the gain of the amplifier 7 becomes maximum. Also, since the inverting input resistor of the amplifier 8 is only R_6, the gain of the amplifier 8 becomes minimum.

On the other hand, when both FETs 4 and 6 are on, the feedback resistance of the amplifier 7 is $(r_1 + R_{on})//r_2$, where R_{on} denotes the conducting resistance of the FETs 4 and 6, $//$ denotes the parallel connection, and r_n ($n = 1$ to 6) denotes the resistance of the resister R_n. Therefore, the gain of the amplifier 7 becomes minimum. Also, since the value of the inverting input resistance of the amplifier 8 is $(r_5 + R_{on})//r_6$, the gain of the amplifier 8 becomes maximum. In the following, it is assumed that the conducting resistance R_{on} of the FETs 4 and 6 is substantially zero under their stable on-condition, or stable period.

When the FETs 4 and 6 are in the intermediate active state between on and off, that is, the above-mentioned changeover period, the gains of the amplifiers 3 and 5 vary with the conducting resistance versus gate voltage characteristics of the FETs 4 and 6.

In order to avoid the singing or howling, it is preferable that the total gain defined by the product of the gains of the receiving and transmitting variable gain amplifiers 3 and 5 is always constant. In the present embodiment, under the stable period during which the on- and off-states of the FETs 4 and 6 are stable, the gate voltages of the FETs 4 and 6 are constant, allowing the resistance values of the FETs 4 and 6 to be constant. Therefore, the total gain can readily be maintained to be constant. However, under the changeover period during which the gains of the amplifier circuits 3 and 5 are changing over, that is, the FETs 4 and 6 are switching between on and off, the total gain may momentarily become larger than the total gain during the stable period, because the gate voltage versus resistance characteristics of the FETs 4 and 6 may relatively be different. This means that the howling may occur during the changeover period. Therefore, it is necessary that the total gain during the changeover period is set to be smaller than the total gain during the stable period. The manner of the setting will be described hereinafter.

Now, it is assumed that both FETs 4 and 6 have the same resistance value R_x for the same gate voltage. Then, the gains $G_R(R_x)$ and $G_T(R_x)$ of the receiving and transmitting variable gain amplifier circuits 3 and 5 are respectively given by,

$$G_R(R_x) = \frac{\dfrac{(r_1+R_x)r_2}{r_1+r_2+R_x}}{r_3} \qquad (1)$$

and

$$G_T(R_x) = \frac{r_4}{\dfrac{(r_5+R_x)r_6}{r_5+r_6+R_x}} + 1 \qquad (2)$$

It is further assumed that the changeover period of the gains of the variable gain amplifier circuits 3 and 5 are mutually equal. Denoting the gains of the receiving and transmitting amplifier circuits 3 and 5 under the stable on-condition of the FET by $G_R(0)$ and $G_T(0)$, respectively, and those under the stable off-condition of the FET by $G_R(\infty)$ and $G_T(\infty)$, respectively, the necessary condition to make the total gain constant is written as,

$$\frac{G_R(0)}{G_R(\infty)} = \frac{G_T(\infty)}{G_T(0)} \qquad (3)$$

From equations (1), (2) and (3), the following relation can be obtained.

$$\frac{r_4\ r_6}{r_4+r_6} = \frac{r_2\ r_5}{r_1} \qquad (4)$$

Here it is assumed that the resistance value of the FET under on-state is zero, while that under off-state is infinite. As a result, the total gain under stable period is given by,

$$G_R(\infty) \cdot G_T(\infty) = G_R(0) \cdot G_T(0) = \frac{r_2}{r_3} \cdot \frac{r_4+r_6}{r_6} \qquad (5)$$

On the other hand, the total gain under the changeover period is obtained from equations (1) and (2).

$$G_R(R_x) \cdot G_T(R_x) = \frac{r_2}{r_3} \cdot \frac{r_4+r_6}{r_6} \left\{1 + \frac{r_4\ r_6}{(r_5+R_x)(r_4+r_6)}\right\} \frac{r_1+R_x}{r_1+r_2+R_x} \qquad (6)$$

In order to make the total gain constant irrespective of the changeover or stable period, the following relation should be held,

$G_R(R_x) \cdot G_T(R_x) = G_R(\infty) \cdot G_T(\infty)$ (7)

Thus, by substituting equations (5) and (6) into (7), one obtains,

$$\left\{1 + \frac{r_4\ r_6}{(r_5+r_6)\ (r_4+r_6)}\right\} \quad \frac{r_1+R_x}{r_1+r_2+R_x} = 1 \qquad (8)$$

By substituting equation (4) into (8), the following relation can be obtained.

$$\frac{1 + \dfrac{r_2\ r_5}{r_1\,(r_5+R_x)}}{1 + \dfrac{r_2}{r_1+R_x}} = 1 \qquad (9)$$

which is rewritten to,

$$\frac{r_2\ r_5}{r_1\,(r_5+R_x)} = \frac{r_2}{r_1+R_x} \qquad (10)$$

From equation (10) one obtains,

$$1 + \frac{R_x}{r_5} = 1 + \frac{R_x}{r_1} \qquad (11)$$

which is rewritten to

$$\frac{R_x}{r_5} = \frac{R_x}{r_1} \qquad (12)$$

Consequently a final result is,

$r_1 = r_5$ (13)

However, the relation (13) can be held only under the assumption that the resistance value R_x of all the FETs varies equally for the change of their gate voltages. In other words, the relation (13) is not necessarily held during the changeover period. The total gain during the changeover period may become larger than during the stable period. Therefore, it is necessary to set the total gain during the changeover period to be smaller than during the stable period. Namely, the following setting is required.

$G_R(R_x)\ G_T(R_x) < G_R(\infty)\ G_T(\infty)$ (14)

from which one obtains by using equations (4), (5),

$r_1 > r_5$ (15)

If the relation (15) is held, the total gain during the changeover period drops below a value less than the total gain during the stable period. The relation (15) means that the resistance of r_5 serially connected to the FET 6 is smaller than the resistance of r_1 serially connected to the FET 4. This can also be held in case the transmitting variable gain amplifier circuit 5 is an inverting amplifier.

Fig. 3 shows a gate-voltage versus a gain characteristics of the FET. A broken line 31 denotes the gain of the amplifier 3, while a single-dotted broken line 32 and a solid line 33 denote the gain of the amplifier 5 and the total gain, respectively. As is obvious from Fig. 3, the total gain during the changeover period is smaller than the total gain during the stable period.

The second embodiment of the present invention will now be explained with reference to Fig. 2. In Fig. 2, the parallel connection of an FET 15 and a resistor R_8 is serially connected to a resistor R_7 of an operational amplifier 16 of a variable gain amplifier circuit 14 in the receiving path. An operational amplifier 19 of a variable-gain amplifier circuit 17 in the transmitting path is an inverting amplifier. The input resistor

R_1: of the amplifier 19 is serially connected to the parallel connection of an FET 18 and a resistor R_{12}.
The gains $G_R(R_x)$ and $G_T(R_x)$ of the amplifiers 14 and 17 are given by,

$$G_R(R_x) = \frac{r_7 + \frac{r_8\ R_x}{r_8 + R_x}}{r_9} \qquad (16)$$

and

$$G_T(R_x) = \frac{r_{10}}{r_{11} + \frac{r_{12}\ R_x}{r_{12} + R_x}} \qquad (17)$$

respectively, where r_n (n = 7 to 12) denotes the resistance of the Resister. When the FETs 15 and 18 are on, the equations (16) and (17) are reduced to,

$$G_R(0) = \frac{r_7}{r_9} \qquad (18)$$

and

$$G_T(0) = \frac{r_{10}}{r_{11}} \qquad (19)$$

respectively, while otherwise they are reduced to,

$$G_R(\infty) = \frac{r_7 + r_8}{r_9} \qquad (20)$$

and

$$G_T(\infty) = \frac{r_{10}}{r_{11} + r_{12}} \qquad (21)$$

respectively.

Since the changeover periods of the gains of the variable gain amplifier circuit 14 and 17 are mutually equal, and since the gains of the circuit 14 and 17 under the stable period should be equal, the following relation must be held.

$$\frac{G_R(\infty)}{GR(0)} = \frac{G_T(0)}{G_T(\infty)} \qquad (22)$$

From equations (18) to (22), one obtains,

$$\frac{r_8}{r_7} = \frac{r_{12}}{r_{11}} \qquad (23)$$

Thus, the total gain during the stable period is.

$$G_R(0) \cdot G_T(0) = \frac{r_7}{r_9} \cdot \frac{r_{10}}{r_{11}} \qquad (24)$$

The total gain during the changeover period is obtained from equations (16) and (17).

$$G_R(R_x) \cdot G_T(R_x) = \frac{r_7}{r_9} \cdot \frac{r_{10}}{r_{11}} \cdot \frac{1 + \frac{r_8}{r_7} \cdot \frac{1}{\frac{r_8}{R_x} + 1}}{1 + \frac{r_{12}}{r_{11}} \cdot \frac{1}{\frac{r_{12}}{R_x} + 1}} \qquad (25)$$

As is similar to the first embodiment, the following relation should be held in order that the total gain during the changeover period is less than that during the stable period.

$G_R(R_x)\ G_T(R_x) < G_R(0)\ G_T(0)$. (26)

If the equations (24) and (25) are substituted into equation (26), one obtains

$$\frac{1 + \frac{r_8}{r_7} \cdot \frac{1}{\frac{r_8}{R_x} + 1}}{1 + \frac{r_{12}}{r_{11}} \cdot \frac{1}{\frac{r_{12}}{R_x} + 1}} < 1 \qquad (27)$$

which is reduced to the final result using the relation (23).

$r_{12} < r_8$ (28)

Therefore, as is similar to the first embodiment, if the resistance r_8 of the resistor R_8 connected in parallel with the FET 15 of the variable gain amplifier circuit 14 in the receiving path is chosen to be larger than the resistance r_{12} of the resistor R_{12} connected in parallel with the FET 18 of the variable gain amplifier circuit 17 in the transmitting path, the total gain during the changeover period can be smaller than the total gain during the stable period.

As is explained above, the present invention utilizes the FET as a variable resistor so as to continuously and smoothly switch the gains of receiving and transmitting paths of the loudspeaking telephone. Moreover, by making the resistance of a resistor serially or parallelly connected to the FET in the receiving path larger than the resistance of a resistor serially or parallelly connected to the FET in the transmitting path, the total gain during the changeover period is made smaller than that during the stable state, so that the singing or howling can hardly occur.

Claims

1. A loudspeaking telephone with a variable gain circuit comprising:

a receiving path including first amplifying means for amplifying a receiving signal by a first gain to provide a receiving speech signal;

a transmitting path including second amplifying means for amplifying a transmitting speech signal by a second gain to provide a transmitting signal;

first means for comparing a signal level on said receiving path with a signal level on said transmitting path to provide a control signal to control said first and said second gains; and

second means responsive to said control signal for switching between said first and second gains to make one of said gains larger than the other of said gains;

wherein the total gain obtained from said first and second gains during the changeover period of said gains is either equal to or smaller than the total gain during the stable period excluding said changeover period.

2. A loudspeaking telephone as claimed in claim 1, wherein said first means comprises:

first and second level detector means for detecting the levels of said receiving and transmitting signal, respectively; and

level comparator means for comparing the output levels of said first and second level detector means with each other to provide the comparison result as said control signal.

3. A loudspeaking telephone as claimed in claim 2, wherein said level comparator means produces a first signal as said control signal when the output level of said first level detector means is larger than that of said second level detector means and produces a second signal as control signal when the output level of said second level detector means is larger than that of said first level detector means; and

wherein said second means controls, in response to said first signals, said first and second gains so that said first gain becomes larger than said second gain, and controls, in response to said second signal, said first and second gains so that said second gain becomes larger than said first gain.

4. A loudspeaking telephone claimed in claim 3, wherein said second means comprises means for maintaining said total gain during said stable period to be constant.

5. A loudspeaking telephone claimed in claim 3, wherein said second means comprises:

first variable resistance means connected to a feedback resistor of said first amplifying means;

second variable resistance means connected to a feedback resistor of said second amplifying means;

first resistance means connected to said first variable resistance means; and

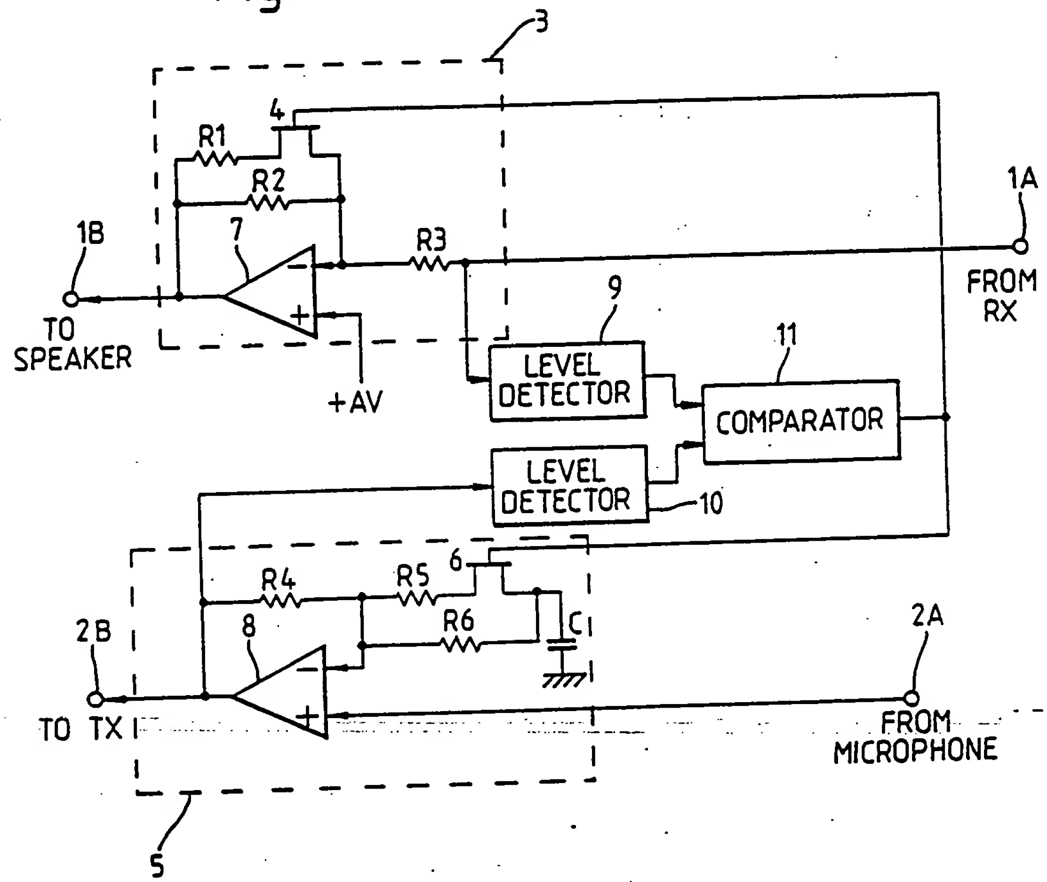
second resistance means connected to said second variable resistance means and having the resistance smaller than that of said first resistance means.

6. A loudspeaking telephone claimed in claim 5, wherein said first and second resistance means are serially connected to said first and second variable resistance means, respectively.

7. A loudspeaking telephone claimed in claim 5, wherein said first and second resistance means are connected in parallel with said first and second variable resistance means, respectively.

8. A loudspeaking telephone as claimed in claim 5, wherein said first and second variable resistance means comprises first and second FETs, respectively, said first and second FETs becoming off when said first signal is applied to the gates thereof, and becoming on when said second signal is applied to the gates thereof.

Fig.1


3
4
R1
R2
1A
1B
7
R3
FROM
RX
9
11
TO
SPEAKER
LEVEL
DETECTOR
COMPARATOR
+AV
LEVEL
DETECTOR
10
6
R4
R5
2B
8
R6
C
2A
TO TX
FROM
MICROPHONE
5

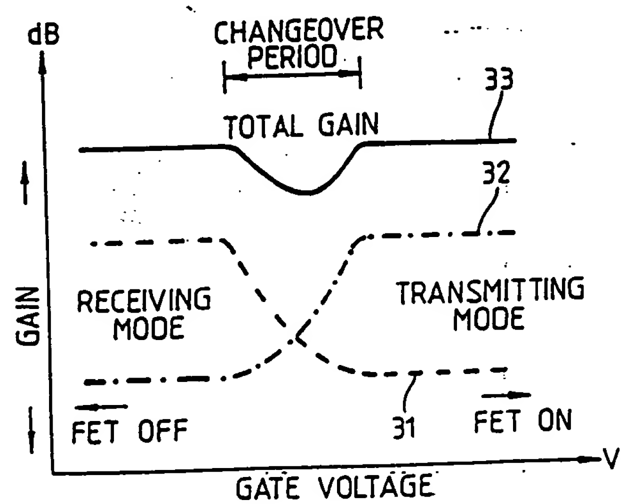

dB
CHANGEOVER
PERIOD
33
TOTAL GAIN
32
GAIN
RECEIVING
MODE
TRANSMITTING
MODE
FET OFF
31
FET ON
V
GATE VOLTAGE

Fig.3

Neu eingereicht / Newly filed
Nouvellement déposé

Fig.2